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EFFECTS OF WHOLE-BODY VIBRATION TRAINING ON THE POSTURAL CONTROL, LOWER BODY STRENGTH, BALANCE CONFIDENCE AND HEALTH-RELATED QUALITY OF LIFE IN COMMUNITY-DWELLING OLDER ADULTS

Lyndsay Foisey

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Abstract

Whole-body vibration training (WBV) may improve balance and strength in older adults. This study investigated the effects of WBV on the balance, lower body strength, balance confidence and quality of life in community-dwelling older adults. Participants (N = 23; 77 ± 7.8 years) were randomized into a WBV group or control group. The WBV group performed eight weeks of WBV; four weeks of standing followed by four weeks of dynamic squats. Control group participants maintained their current lifestyles. Postural control, the Sit-to-Stand test, the Berg Balance Scale, the Activities-specific Balance Confidence Scale and the Medical Outcome Survey Short-Form 36 were tested at baseline and post-intervention. Analyses revealed that WBV did not affect the postural control, quality of life or balance confidence of the WBV group. However, the WBV group improved on functional balance and lower body strength measures. WBV may be an effective method for improving muscle performance in older adults. Future research is warranted on WBV for low functioning older adults.

Keywords: Whole-body vibration, balance, balance confidence, older adults

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List of Abbreviations

CNS	Central Nervous System
WBV	Whole-body Vibration
TVR	Tonic Vibration Reflex
COP	Centre of Pressure
RAPA	Rapid Assessment of Physical Activity
SF-36	Short-form 36
ABC	Activities-specific Balance Confidence Scale
STS	Sit-to-Stand
BBS	Berg Balance Scale
HRQOL	Health-related Quality of Life
IG	Intervention Group
CG	Control Group
ANOVA	Analysis of Variance
DOMS	Delayed-onset Muscle Soreness
CSEP	Canadian Society for Exercise Physiology
VON	Victorian Order of Nurses Cherryhill Healthy Ageing Program

Introduction and Literature Review

Falls among older adults are a common occurrence, as 30% of seniors 65 years of age and older fall at least once per year (Gillespie et al., 2009; Liu – Ambrose, Khan, Eng, Lord, & McKay, 2004). Further, the incidence of injuries and deaths due to falls continues to rise (Liu – Ambrose et al., 2004). Fall risks increase due to age-related physiological changes such as sarcopenia, decreased balance, and a loss of motor control. Moreover, psychological issues such as fear of falling may magnify the risk of a fall (Shumway – Cook & Woollacott, 2001). Older adults with a fear of falling tend to restrict their activities, leading to further declines in functional mobility, balance and social life; all of which contribute to a lowered quality of life (Myers, Fletcher, Myers & Sherk, 1998). Physical activity interventions have shown to improve balance and strength, as well as balance confidence and quality of life (Binda, Culham & Brouwer, 2003; Elavsky et al., 2005; Liu-Ambrose, et al., 2004). However, many older adults are unable or unwilling to participate in regular physical activity. A new method of balance and strength training that shows promise is whole body vibration (WBV) training.

Multiple studies have shown support for WBV training exposure as an exercise intervention for older adults (Bautmans, Van Hees, Lemper & Mets, 2005; Bogaerts, Verschueren, Delecluse, Claessens, & Boonen, 2007; Bruyere et al., 2005). Several benefits of WBV interventions include a decrease in training time and physical exertion than a traditional exercise program; yet WBV potentially displays similar, even superior, results. WBV training typically involves participants standing or performing body weight exercises on a vibratory platform that generates vertical oscillations through the point of contact, which is primarily at the feet. Vibration machines are set at a particular frequency (15 – 60 Hz) and amplitude (1 – 10 mm), which stimulate a neuromuscular response that is believed to lead to results such as improvements in lower limb strength (Delecluse, Roelants & Verschueren, 2003; Rees, Murphy, & Watsford, 2007; Roelants, Delecluse & Verschueren, 2004).

Background and Significance

What is Postural Control?

Without proper postural control, humans would be unable to perform essential daily activities such as walking or sitting (Shumway-Cook & Woollacott, 2001). Postural control is defined as "...controlling the body's position in space for the dual purposes of stability and orientation." (Shumway-Cook & Woollacott, 2001, p. 164). To maintain postural control and not lose balance, the centre of mass must be within the base of support (Kerr, 2010), which is the area of the body in contact with the support surface (typically the feet). Postural control is the complex integration and coordination of the sensory system, motor system and central nervous system (CNS; Widmaier, Raff & Strang, 2004). In order to maintain postural control, the CNS needs to know when and how to apply muscular forces to restore stability, and also to be aware of the orientation of the body (Widmaier et al., 2004). This information is retrieved for the CNS by the sensory system. The sensory system includes the visual, somatosensory (proprioceptive, cutaneous and joint receptors) and vestibular systems. Through these systems, the CNS identifies the orientation of the body in terms of gravity and the environment (Shumway-Cook & Woollacott, 2001). Information from the visual, somatosensory and vestibular systems is then sent to the brain, where it is integrated and interpreted to maintain postural control (Shumway-Cook & Woollacott, 2001). During quiet stance, for example standing still with arms relaxed by the sides, all three sensory systems are attuned to maintain postural control in a healthy adult. When balance is perturbed by sudden unexpected movements, for example standing on a bus while it is in motion, the sensory system will use strategies to organize the balance information for proper postural control (Woollacott, 2007).

The Effects of Age on Postural Control

When maintaining postural control the body utilizes the most appropriate sensory system depending on task, age, and the surrounding environment (Shumway-Cook & Woollacott 2001). The ability to organize sensory information effectively and to maintain balance control is essential to daily living for the older adult (Lin & Woollacott, 2005). For instance, balance is required for functional movements such as dressing oneself and getting out of the bath. However, it has been established that balance deteriorates with increasing age, potentially putting one at risk for a fall (Tinetti, 1986). One of the reasons for this may be sensory system dysfunction (Shumway-Cook & Woollacott 2001). The sensory strategies of older adults may be damaged, leading to multisensory (visual, vestibular, somatosensory) deficits with increasing age (Woollacott, 2007). This can create a latency in response to balance challenges, resulting in a higher fall risk (Shumway-Cook & Woollacott, 2001). The sensory losses associated with the decline of the somatosensory, visual and vestibular systems are strongly related to increases in body sway and loss of balance, both of which are common risk factors for falls (Serrador, Lipsitz, Gopalakrishnan, Black & Wood, 2009; Teasdale, Lajoie, Bard, Fleury & Courtemanche, 1993).

According to Shumway-Cook and Woollacott (2001), the somatosensory system becomes impaired with age, leading to diminished sensitivity to proprioception such as fine touch, pressure and vibration. For example, it was found that a lack of vibration detection on the skin was indicative of somatosensory dysfunction (Lin & Woollacott, 2005). This can place older adults at a higher risk of a fall (Lin & Woollacott, 2005).

The visual and vestibular systems may also decline in function with increasing age. There is evidence of a 40% decrease in vestibular hair and nerve cells by age 70 (Rosenhall & Rubin, 1975). The visual system may lose effectiveness in older adults, as there is less light transmitted to the retina, decreased acuity and decreased contrast sensitivity, all of which contribute in impaired vision (Berk, 2008). Brooke-Wavell, Perrett, Howarth & Haslam (2002) found that when removing the visual field, the body sway of older women aged 65-75 years significantly increased, indicating the importance and reliance on the visual system for postural control.

Balance Confidence and Fear of Falling

Fall risk factors may not be strictly physiological in nature. The psychological trauma of a fall, such as post-fall syndrome (Murphy & Isaacs, 1982), is strongly related to declines in balance and mobility (Liu-Ambrose et al., 2006) and health-related quality of life (Suzuki, Ohyama, Yamada & Kanamori, 2002). These functional declines are typically self-imposed rather than due to injury, as older adults with a fear of falling tend to restrict their activities (Powell & Myers, 1995). Powell & Myers (1995) refer to this phenomenon as a loss of balance confidence, or a fear of falling. Balance confidence is an older adult's self-efficacy in their ability to maintain balance in everyday situations, such as walking up stairs or standing on a chair to reach for an object. Self-efficacy, based on Bandura's theory (Bandura, 1977), is the perceived capability or self-confidence a person has to perform an activity. Balance confidence plays a significant role in an older adult's perceived capability of their balance control, as a low balance confidence in both fallers and non-fallers can be predictive of future balance and mobility impairments, as well as future fall risks (Blanchard, Myers & Pearce, 2007). In fact, approximately 30% of non-fallers report a fear of falling; this doubles to nearly 60% once a fall occurs (Tinetti et al., 1994). Furthermore, a high perceived risk of falling is related to depressive symptoms, neuroticism and decreased executive function (Delbaere, Close, Brodaty, Sachdev & Lord, 2010). Delbaere et al. (2010) found that individuals with a low perceived risk of falls continued to exercise and held a positive outlook out on life, both of which acted as a protective factor for falling.

Balance training programs have been shown to increase an older adult's balance confidence (Myers et al., 1998), especially for those residing in a community setting (Zijlstra et al., 2007). In a study investigating the effects of a Tai Chi program on the fear of falling, Taggart (2002) found that after 3 months of Tai Chi sessions, performed twice weekly, balance and mobility increased, and fear of falling decreased compared to a control group. In addition, physical activity programs such as resistance training have also improved balance confidence (Liu-Ambrose et al., 2004).

Balance Exercise Programs for Older Adults

Psychological and physiological factors may significantly increase the probability of a fall, and both should be considered when designing a falls prevention program (Delbaere et al., 2010). Although age-related effects on balance can be detrimental to quality of life, there is evidence that exercise can retrain balance and prevent falls (Tinetti & Kumar, 2010). In fact, regular exercise may decrease fall risk from 54 down to 41% (Delbaere et al., 2010). The optimal balance exercise prescription, however, remains unknown (Shumway-Cook & Woollacott, 2001), despite the fact that it is the single most studied factor in the falls prevention literature (Tinetti & Kumar, 2010). Evidence suggests that a combination of cardiovascular, muscle strengthening and balance exercises may improve balance (Shumway-Cook & Woollacott, 2001). Evidence from a systematic review and meta-analysis demonstrated that exercise – with the exception of cardiovascular exercise - decreased fall risk by 17% (Sherrington et al., 2008). It was stated that cardiovascular endurance exercise, such as a walking program, does not improve balance. Sherrington et al. (2008) postulated that this finding may be due to the exposure of additional fall risks. Another suggestion was that perhaps muscle strengthening and balance training are more related to everyday activities that require balance. This is further supported by several studies that found both strengthening and balance training improved balance (Bird, Hill, Ball & Williams, 2009; Lord et al., 2005). In their crossover study, Bird et al. (2009) investigated the effects of flexibility versus strength training on balance. Sedentary older adults (N = 32, ~ 67 years) were allocated into two groups – resistance or flexibility. Training sessions were 4 months in duration, and participants exercised three times per week. Resistance training sessions included functional exercises such as push-ups, lunges and step-ups. The authors followed the overload principle such that resistance was progressively increased when the three sets became too easy. In order for muscular adaptation to occur, a progressive overload principle should be implemented (American College of Sports Medicine (ACSM), 2010). Flexibility sessions included two stretches per major muscle group, equating to 16-20 stretches in total. Bird et al. (2009) found that balance improved in both groups. Strength gains, however, were only observed in the resistance training group.

Similar findings were reported by Islam et al. (2004), where the efficacy of a balance training program was evaluated. Participants (N = 29 ~76 years) were randomly assigned to either a training or control group. The training was comprised of a supervised 12-week balance and strengthening program. Exercises were performed twice per week and included tandem stance and body weight exercises. The control group was instructed to maintain their current lifestyles. Significant improvements in balance and lower body strength were found for the training group compared to the control group. Both static balance, as measured by standing on one leg with eyes closed, as well as lower body strength, improved by 82% and 20% respectively. There were no changes reported for the control group. The authors concluded that balance and strength training may reverse age-related declines in balance.

Muscular strength decreases with age, as 15% is lost between the ages of 60 to 70 years. This doubles to 30% loss after 80 years of age (ACSM, 2010). This is due to the condition sarcopenia, where muscle tissue decreases in size and is replaced with connective tissue and fat cells (Shumway-Cook & Woollacott, 2001). Sarcopenia can lead to a decrease in function and daily activities, and even a loss of independence (ACSM, 2010). When strength falls below the force threshold needed for an activity of daily living, this can lead to frailty and functional disability (Shumway-Cook & Woollacott, 2001). It has also been noted that there is a greater loss of strength in the lower body than the upper body (ACSM, 2010). This can have major detriments on the daily living of an older adult, as muscle weakness in the lower body affects daily activities such as standing, walking and sit-to-stand positions (Seguin & Nelson, 2003). There is much support that lower body strength plays a large role in preventing falls in older adults (Robsinson, Gordon, Wallentine & Visio, 2004; Sousa & Sampaio, 2005).

Decreased strength has shown to be significantly correlated to poor results on clinical balance measures such as the Dynamic Gait Index, Berg Balance Scale and the Self-Perceived Balance Test (Shumway-Cook & Woollacott, 2001). The role of strength in preventing falls was demonstrated in a study by Daubney & Culham (1999), where the authors investigated the degree to which strength contributes to postural control. Community-dwelling older adults (N = 50) averaging 75 years of age were measured using the Berg Balance Scale, the Functional Reach Test and the Timed Get Up and Go test. The authors found that 58% of the Berg Balance Scale score could be explained by lower body strength. Similarly, lower body strength played a role in postural control for the Functional Reach Test and Timed Get Up and Go test, as 13% and 48.4% of the results were due to strength, respectively.

Although there is evidence that balance and muscle strengthening exercises improve balance control and decrease fall risk in older adults, the exact exercise prescription is still unclear (Lord et al., 2005). In addition, there exists much variation between study designs (Shumway-Cook & Woollacott, 2001), making it difficult to prescribe an efficient and effective balance training program.

Whole-Body Vibration Training

A relatively new method of effective and efficient muscle strengthening and balance training is whole-body vibration (WBV) training. Vibration as an exercise modality has gained much interest, and the WBV training literature regarding vibration exercise has expanded over the past decade (Lau, Teo, Yu, Chung & Pang, 2011). WBV training typically consists of standing or exercising on a vibrating plate for single or multiple sessions. Vibrations are transmitted through the lower body from the point of contact, which is normally at the feet. There are two types of vibration platforms typically used in research; vibratory platforms that oscillate vertically or pivot from left to right, like a teeter-totter.

The Tonic Vibration Reflex

It is theorized that improvements in postural control and lower body strength from vibration exercise is due to a reflexive muscle contraction created by vibration (Carlucci, Mazza & Cappozzo, 2010). This contraction is referred to as the tonic vibration reflex (TVR) (Eklund & Hagbarth, 1966). Sensory receptors, such as the muscle spindle, are stimulated by the vibration (Shumway-Cook & Woollacott, 2001), which activate motor neurons (Cardinale & Bosco, 2003). As a result, the muscle contracts (Cardinale & Bosco, 2003). In fact, electromyographic (EMG) readings of muscle activity during WBV training are reportedly greater in comparison to performing the same exercise without vibration (Hazell et al., 2007; Roelants et al., 2004a). For example, Hazell et al. (2007) reported an increase in EMG activity in the vastus lateralis muscle from 3.7% to 8.7% when performing dynamic squat exercises on the vibration platform versus no vibration. Furthermore, Roelants et al. (2004a) reported increases of 92.5% - 301% in the quadriceps muscles compared to controls while performing squat exercises. The enhanced muscle activation from TVR is speculated to be the reason for increases in jump height and muscle strength after acute WBV training exposure (Bosco et al., 2000; Issurin et al., 2005; Roelants et al., 2004).

In addition to the TVR, the sensory system is stimulated by vibration (Lau et al., 2011). Somatosensory receptors, such as mechanoreceptors, play a role in postural control and are excited by vibration (Shumway-Cook & Woollacott, 2001). Bogaerts et al. (2007) speculate the postural control improvements from their 12-month WBV training study may have been due to somatosensory system stimulation. It is speculated that this increase in sensory input, as well as reflexive muscle activity, could translate into gains such as improved postural control and gait (Lau et al., 2011). According to Rees, Murphy & Watsford (2008), the potential sensorimotor adaptation from WBV training is an area in need of further research.

WBV Training and Older Adults

WBV training has been ascribed as a safe and effective alternative to traditional exercise for older adults (Bissonnette, Weir, Leigh & Kenno, 2010; Carlucci et al., 2010; Rittweger, 2010). There is evidence that low to moderate intensity WBV training has improved postural control (Bogaerts et al., 2007; Bruyere et al., 2005; Rees et al., 2008) and lower body strength in older adults (Rees et al., 2007; Roelants et al., 2004). Muscle strengthening exercises are recommended to counter age-related declines in function and balance (Canadian Society for Exercise Physiology (CSEP), 2011). Loads of up to 70-90% on the muscle, however, must be attained to achieve gains (Bogaerts et al., 2007a). This can be too demanding for some older adults, especially residents in a long-term care facility (Bautmans et al., 2005). WBV training may be an appealing alternative to older adults, especially those who are disinterested or unable to participate in conventional exercise (von Stengler, Kemmler, Engelke & Kalendar, 2010).

WBV Training Interventions – Standing-only program designs

Several studies have reported neuromotor benefits of WBV training, such as improved muscular strength, balance and gait by standing with slightly flexed and relaxed knees on a pivoting vibration platform (Bruyere et al., 2005; Cheung et al., 2007; Runge, Rehfield & Resnicek, 2000). WBV training was reported to improve lower body strength by 18% in older adults living in a retirement community (Runge et al., 2000). In addition, WBV training improved balance control and gait in long-term care residents (Bruyere et al., 2005). Bruyere et al. found that Tinetti test scores, a clinical test to measure balance as well as mobility, improved significantly after six weeks compared to a physical therapy-only group. The Tinetti test is a performance-oriented test to identify limitations in mobility and gait (Tinetti, 1986). Aspects of the Tinetti test include balancing with eyes closed and one leg standing balance. Participants in the intervention group improved significantly by 3.5 out of 16 points on the Tinetti test. The balance score of the control group decreased by 0.3 points. These results coincide with other standing-only programs for inactive community-dwelling older adults (Cheung et al., 2007).

The WBV Training Overload Principle

Although standing-only programs may be beneficial for some older adults, this may not be applicable for the active older adult due to factors such as boredom and insufficient exercise intensity. In addition, the overload principle was not incorporated in any of the standing-only WBV training programs. The only study to provide details of a WBV training overload principle is Roelants et al. (2004). The WBV training overload principle, according to Roelants et al. (2004), is the systematic increase of training volume over the training period. At the beginning of their WBV training protocol, Roelants et al. (2004) incorporated a low training volume and intensity. As the study progressed, the frequency and amplitude of the vibration were slowly increased, as well as the number of exercises and the length of training sessions. Additional exercises were implemented along with shortened rest times. A similar overload principle was employed in the present research when designing and implementing the WBV training protocol.

WBV Training Interventions – Exercise Program Designs

The majority of the WBV training and older adult literature has included static and dynamic exercise protocols, specifically lower body strengthening exercises. Several studies that incorporated dynamic exercises in the protocol reported improvements in strength and/or balance (Bautmans et al., 2005; Bogaerts et al., 2007; Rees et al., 2008). For example, knee extension strength improved in post-menopausal women after 6 months of WBV training (Roelants et al., 2004). Knee extension strength was measured by a dynamometer at 1%, 20%, 40% and 60% of maximum extension strength. The WBV group performed squat exercises on a vibration platform, whereas the control group performed total body exercises without the vibration stimulus.

In a longitudinal study, von Stengler et al. (2010) compared three groups: vibration, fitness control and control for 18 months (N = 151) to evaluate the effects of WBV training on an older adult population aged 65 – 76 years. The intervention and fitness control group performed the exact same exercise protocol of cardiovascular and total body strengthening exercises. The only difference between the two groups was that the vibration group performed exercises such as one-legged squats, heel raises and leg abductions with the vibration stimulus. The time spent exercising increased systematically at 3, 6 and 12 months as per the overload principle. Although for both training groups there were minor effects on body composition, muscle strength and power increases tended to favour the intervention group. In addition, strength and power increases, as measured by countermovement jumps and trunk flexion, significantly improved in the intervention group compared to the control group.

Some WBV training studies did not find between group differences. Rees et al. (2007) found that after eight weeks, WBV training and the fitness control group achieved similar improvements in knee-extension strength and mobility tests, such as the Sit-to-Stand test, the Timed Up and Go test and the 5-metre fast walk test. In addition, Bogaerts et al. (2007a) reported that a WBV training program improved lower body strength compared to baseline tests in their one year randomized-control study (n = 97). Although both the fitness control and WBV training groups achieved similar results, the fitness group performed a 1.5 hour program of cardiovascular, resistance training, balance and flexibility exercise. In comparison, the WBV training group exercised for only 40 minutes. The resistance training portion of the fitness control group consisted of a total body regimen, and included leg press and leg extension machines. The treatment program consisted of squat and lunge exercises on the vibration platform. Isometric knee strength was measured with a dynamometer and countermovement jumps. Leg strength improved significantly by 9.8% and 13.1%

for the vibration and fitness groups respectively; explosive strength improved significantly by 10.9% and 9.8%.

In addition to strength, several studies report improved balance (Bogaerts et al., 2007; Bruyere et al., 2005; Rees et al., 2008) and gait (Bautmans et al., 2005; Furness, Maschette, Lorenzen, Naughton & Williams, 2010) from static and dynamic WBV exercise programs. Rees et al. (2008) investigated the effect of WBV training on the balance of older adults and found that the WBV group improved compared to fitness and control groups. Men (n = 23) and women (n = 20) with an average age of 73.5 years were randomized into WBV, exercise control or control groups. Both WBV and exercise control groups performed the same static and dynamic exercises, three times per week for 8 weeks. The only discrepancy between the training groups was the WBV performed the exercises while receiving vibration on a pivoting vibration plate. For the first half of the study, static exercises (standing with knees slightly bent) were performed. For the second half of the study, dynamic exercises such as squats and calf raises were performed. Postural control was evaluated with the one-legged postural steadiness test (OLPS) on a force plate. The OLPS is a measure of the centre of pressure while balancing on one foot. Although baseline postural control scores were slightly poorer for the WBV group, post-test postural control scores were superior to both control groups. Rees et al. (2008) concluded that WBV training can improve postural control in older adults, especially those with poor postural control. These improvements from WBV training may be due to sensorimotor stimulation (Bogaerts et al., 2007; Rees et al., 2008). However, it is still relatively unknown to what extent the sensory system is affected by WBV training.

In their 12-month WBV training longitudinal study, Bogaerts et al. (2007) investigated the effects of WBV training on postural control in older adults. Community-dwelling older adults (N = 224) between the ages of 60 and 80 years were randomized into intervention, traditional exercise or control group. The WBV training intervention was performed three times per week for 40 minutes and consisted of lower body exercises such as squat and calf raises. The fitness group performed cardiovascular exercises at an intensity of 70-85% of heart rate reserve as well as resistance training and balance exercises three times per week for 1.5 hours. Weight training exercises for this group targeted the whole body. The fitness control group also performed flexibility and balance conditioning exercises such as standing on one leg. Programs for both groups incorporated the overload principle. Postural control was evaluated with the sensory organization test, which computes body sway and percentage of falls via computerized dynamic posturography. During the test, the effectiveness of the sensory system to maintain balance in sensory-challenged conditions, such as sway-referenced or normal support surfaces and visual surround are assessed. Specifically, sway-referenced refers to the support surface or visual surround that moves with the sway of the participant, therefore providing incorrect balance information to the visual, vestibular and somatosensory systems (Bogaerts et al., 2007). The sensory organization test conditions include: 1) normal vision and support surface, 2) eyes closed and normal support surface, 3) sway-referenced vision, normal support surface 4) normal vision, sway-referenced support surface 5) eyes closed, sway-referenced support surface and 6) sway-referenced vision and support surface. At post-intervention measures, Bogaerts et al. (2007) found the number of falls during the sensory organization test had significantly decreased for both the WBV training and fitness groups.

Bogaerts et al. may be one of the first to investigate the potential sensory-specific effects of long-term WBV training on the postural control of older adults. In addition to the sensory organization test, anterior-posterior sway and a motor control test were evaluated at baseline and post-test. Bogaerts et al. (2007) reported similar postural control improvements for the WBV group and the fitness group in the eyes-closed plus unstable support surface condition. Moreover, the WBV group experienced fewer falls compared to controls for sway in the anterior direction, whereas the fitness group did not experience this phenomenon. Bogaerts et al. (2007) commented that WBV training is an efficient method of balance training for older adults.

Although the sensory organization test is a valuable tool to predict fall risk (Buatois, Gueguen, Gauchaud, Benetos & Perrin, 2006), static posturography may be a better prediction tool for future fall risk (Maki, Holliday & Topper, 1994; Piirtola & Era, 2006). In addition, Bogaerts et al. (2007) point out the sensory organization test does not detect subtle changes in balance (Gustafson, Noaksoon, Kronhed, Moller & Moller, 2000), nor does it provide specific sensory information. Moreover, Bogaerts et al. (2007) mentioned that they did not measure sway in the mediolateral direction, which is known predict future falls (Piirtola & Era, 2006).

While the body of literature on WBV training continues to grow, there is a need for more evidence to prove that WBV training decreases sway and fall risk (Rittweger, 2010). Many studies use outcome measures that lack sufficient validity and reliability (Merriman & Jackson, 2009), and there is great variation between WBV training protocols (von Stengler et al., 2010). Moreover, it has not yet been quantified whether neuromotor improvements from WBV training translate to increases in perceived balance capabilities, such as balance confidence - both of which are important to wellbeing (Powell & Myers, 1995). There is a need for a basic, safe and effective WBV training program – proven to result in functional and neuromotor improvement – that is applicable and appealing to community-dwelling older adults.

Purpose

The present study followed a parallel randomized design to determine whether eight weeks of WBV training at three sessions per week would improve balance in community-dwelling older adults. The purpose of this study was to investigate whether WBV training improves postural control, lower body strength, health-related quality of life and balance confidence. The following research questions were addressed:

RQ1: Will there be an improvement in postural control, lower body strength, balance confidence, health-related quality of life in community-dwelling older adults from baseline (Time 1) after eight weeks of WBV training (Time 2)?

RQ2: Does eight weeks of WBV training improve postural control, lower body strength, balance confidence, health-related quality of life in community-dwelling older adults in comparison to the control group?

Method

Participants

Inclusion/Exclusion Criteria

Sixty-five years of age was selected as the minimum age for participation as this is the average age in most studies of WBV and older adults (Roelants, Delecluse & Verschueren, 2004). All participants were free of contraindications to exercise according to the WAVE (WAVE, 2009) criteria and the ACSM (2010). The exclusion criteria included the following: acute mental status or delirium, cerebral haemorrhage within the past 3 months, eye surgery within the past 6 weeks, a fractured bone in healing stages, bleeding haemorrhoids, acute illness or change in symptoms, retinopathy, systemic infection, blood pressure higher than 160/100 that was not controlled by medication, uncontrolled diabetes, epilepsy, gallstones, kidney stones, acute inflammations, joint problems, serious cardiovascular diseases, joint implants, recent thrombosis, back problems such as hernias or tumours, recent operative wounds, intense migraines, permanent bed-bound status, severe cognitive impairment or behavioural disturbance, unstable abdominal, thoracic, or cerebral aneurysm, untreated severe aortic stenosis, wheelchair use, assistance with walking in a room, transfers, dressing or eating.

In addition to the above contraindications, eligible participants must not have been exercising regularly at a vigorous intensity (Bogaerts et al., 2007; Machado et al., 2010). This was incorporated to ensure that participants were untrained and was verified with the Rapid Assessment of Physical Activity Scale

(RAPA; Topolski et al., 2006). The RAPA is a validated tool used to measure physical activity level in adults older than 50 years of age (Topolski et al., 2006). The RAPA evaluates physical activity level in two categories – Aerobic and Strength/Flexibility activity. Participants rated their aerobic activity level on a scale from 1 (rarely or never do any physical activity) to 7 (>20 minutes of vigorous activity, 3 days or more per week). A score of 7 for the Aerobic category was set as the exclusion criteria. The Strength/Flexibility category was scored as 0 (no activity) to 3 (performs both strength and flexibility exercises once per week or more). Further information regarding the survey can be found in Appendix A.

Recruitment

Sample size was calculated based on previous data from a vibration and balance study with older adults (Rees et al., 2008). The α-level was set at .05 and power was determined as .80. It was calculated that 16 participants were needed for each group, equalling a total of 32 study participants. This study was approved by the University of Western Ontario Health Sciences Research Ethics Board (Appendix B).

From January 2010 to August 2010, participants were recruited by contacting community organizations such as the Cherryhill VON Healthy Ageing Program, church organizations and senior community centres in the London area. Posters were displayed in high traffic areas at the community centres (Appendix C). Some participants were also recruited by word-of-mouth.

Fifty-one people contacted the investigator to volunteer for the study. Out of the 51 potential participants, 10 were not eligible due to study exclusion criteria, eight did not return phone calls, eight were not interested, and one passed away shortly after initial contact from the investigator. Due to time constraints, however, only 24 participants were recruited. Participants were randomized to either intervention group (IG) or the control group (CG) using a random number generator (Microsoft Excel, 2007). The allocation ratio was 1 : 1, therefore 12 participants were enrolled in the IG and 12 in the CG. One CG participant was lost-to-follow-up due to disinterest in participation. This participant had completed Time 1 measures, but they dropped out of the study prior to completing measures at Time 2 and thus was removed from the study. Therefore, there were 12 participants in the IG and 11 in the CG. Table 1 includes participant demographic information.

Table 1

Demographic information of Intervention Group (IG) and Control Group (CG) groups

Parameter	CG (n = 11)	IG (n =12)
Age (years)	78.2 ± 8.3	76.0 ± 7.5
Sex	Female: n = 11	Female: n = 8 Male: n = 4
Height (cm)	158.9 ± 10.1	162. 8 ± 8.7
Weight (kg)	59.7 ± 6.8	69.8 ± 10.7
Number of comorbidities	1.5 ± 0.7	1.6 ± 1.9
RAPA[a]	Aerobic: 5.4 ± 1.0 Strength and Flexibility: 2.1 ± 1.7	Aerobic: 4.5 ±1.4 Strength and Flexibility: 0.5 ± 1.0

Note. Values are presented as mean ± standard deviations.

[a] Rapid Assessment of Physical Activity (RAPA): Aerobic Fitness Score – 1= Sedentary; 2= Under-active; 3= Under-active regular - light activities; 4-5 = Under-active regular; 6-7= Active. Strength and Flexibility Fitness Score – 0 (None); 3 (Active).

Outcome Measures

Postural Control

A force plate (Kistler Force Plate Platform, Model 9278B) was used to quantify sway as a measure of static balance. A force plate measures the ground reaction forces and position of the centre of pressure (COP) of each test participant. Force plates are frequently used to measure static balance as they are highly sensitive and accurate (Crilly, Willems, Trenholm, Hayes & Delaquerriere-Richardson, 1989; Piirtola & Era, 2006). Data from the force plate was collected for 60 seconds per trial at a 100 samples per second (Carlucci et al., 2010). The data was then filtered with a fourth-order Butterworth filter at a cut-off frequency of 4Hz (McClenaghan et al., 1996). The force plate analog signals were amplified via a separate 8-channel charged amplifier (type 9865C) and converted from analog to digital through a 16-bit analog/digital card (National Instruments). A computer program (LabView; National Instruments) was customized to collect force plate data. The parameters for centre of pressure collected were : mean mediolateral centre of pressure (mm), mean anterioposterior centre of pressure (mm), mediolateral variability (mm), anterioposterior variability (mm), mediolateral sway range (mm), anterioposterior sway range (mm), sway velocity (mm/s), and radius enclosing 90% (m). See Appendix D for the descriptions and formulas of the summary measures.

Static posturography with eight sensory-challenged conditions was used as a measure of postural control. Quantifying postural control using a force plate and altered sensory conditions has been found to be both valid and reliable (Piirtola &Era, 2006; Woollacott, 2007), and may predict future falls in subjects with no apparent balance problems or fall history (Pajala et al., 2008).

For each of the eight sensory balance conditions, participants stood upright on a force plate. The balance conditions exemplified each sensory system and the ability of the participant to organize sensory strategies. The visual input was altered by having participants close their eyes (Prieto, Myklebust, Hoffmann, Lovett & Myklebust, 1996). By removing visual input, the visual system could not provide cues for balance control, forcing the CNS to adapt and give weight to more appropriate sensory input (Shumway-Cook & Woollacott, 2001). The somatosensory input was altered by standing on a two-inch piece of foam on the force plate (Low Choy, Brauer, & Netz, 2003; Rittweger, 2010); and vestibular input was altered by extending the neck and focusing on a target, a 12 inch piece of dark tape (Simoneau, Leibowitz, Ulbrecht, Tyrrell & Cavanagh, 1992) on the ceiling. The eight trials are listed in Appendix E.

The altered sensory conditions on the force plate were randomized using a random number generator program (Microsoft Excel, 2007) for each participant at Time 1 and Time 2 to prevent order effects (Buatois et al., 2006). Base of support (the distance between the 5th metatarsals) was measured in centimetres once participants stood comfortably on the force plate for standardization between baseline and post-tests (Pajala et al., 2008). Participants were asked to remove footwear before standing on the force plate. Once on the force plate, each participant was instructed to stand upright and as still as possible. A 10 cm diameter circle was placed on a bulletin board situated 2 metres from the participant, in their line of vision (Carpenter, Frank, Winter & Peysar, 2001). Once the participant and the force plate technician were ready to commence the trial, the participant was instructed on which balance condition they were to complete. Each condition lasted 30 seconds with a 2 minute break between conditions (LeClair & Riach, 1996). For safety two volunteers stood closely to participants as spotters. Participants could remain standing or sit in a chair during the breaks.

Functional Balance (Berg Balance Scale)

The Berg Balance Scale (BBS; Berg, Wood-Dauphinee, Williams & Gayton, 1989) is a clinical measure of balance and mobility in older adults. It is frequently used in a medical setting to determine fall risk (Lajoie & Gallagher, 2004). Concurrent validity with the Tinetti test is .91 (Shumway et al., 1997), and inter-rater reliability is also very good (0.96; Shumway et al., 1997). Participants were instructed to perform 14 different balance tasks and were scored based on their ability to successfully complete each task. Each task was rated out of 4 (0 – unable to perform the task; 4 – completes task perfectly) by the investigator. Once all 14 tasks were completed, scores were summed and totalled out of a possible 56 points for each participant. A score of 0 – 20 indicates a high fall risk, 21-40 points indicates a medium fall risk and 41-56 indicates a low fall risk. Lajoie et al. (2004) found that a cut-off score of 46 points or below can predict falls. A higher score on the BBS is associated with a decreased fall risk in older adults (Shumway et al., 1997). Additional information on the BBS can be found in Appendix F.

Lower Body Strength (Sit-to-Stand test)

The Sit-to-Stand (STS; Bohannon, 1995) is a simple, yet reliable tool (ICC = 0.81; Schaubert & Bohannan, 2005) to measure lower extremity strength in older adults (Bohannon, 1995). It is also a sensitive and specific tool (Bohannon, 2009). Instruments required for the Sit-to-Stand included an armchair 40 cm in height and a stop watch. Participants were instructed to sit with their feet flat on the ground, arms at their sides, and to perform five sit-to-stands as quickly as possible. Time to perform the test was recorded in seconds.

Balance Confidence

Balance confidence was measured with the Activities-Specific Balance Confidence Scale (ABC; Powell & Myers, 1995). The ABC assesses an older adult's self-efficacy in their ability to maintain balance in everyday situations, such as walking up stairs or standing on a chair to reach for an object. The ABC has been shown to have very good internal consistency (Cronbach's α .95; Talley et al., 2008) and convergent validity with the Physical Self-Efficacy Scale ($r = .63$; Powell & Myers, 1995). Participants were instructed to rate their balance confidence for each of 16 items on the ABC on a scale from 0% (no balance confidence) to 100% (excellent balance confidence). A score of 50% or less denotes low functional mobility (Myers et al., 1998), and a cut-off score of 67% may significantly predict fall risk (Lajoie et al., 2004). Further information can be found in Appendix F.

Health-related Quality of Life

The Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36; Ware & Sherbourne, 1992) is a valid (discriminant validity .92; McHorney et al., 1994) and reliable tool (Cronbach's $\alpha > .85$; Brazier et al., 1992) administered to evaluate health-related quality of life (HRQOL; Brazier et al., 1992; McHorney et al., 1994). The 36-item survey appraises quality of life categories such as physical function, role limitations due to physical and emotional health, social function, bodily pain, general mental health, energy level and general health perceptions. Each of the categories was rated by the participant on a spectrum of poor health (0 points) to excellent health (100 points). Additional information on the SF-36 can be found in Appendix F.

Procedures

Prior to commencing baseline testing (Time 1), the letter of information (Appendix G) was read by the participant. Each participant was asked by the investigator if they had any questions about the study and their participation. Afterwards the participants signed the consent form. Following the demographic questionnaire (Appendix H) and exclusion criteria checklist, participants completed the RAPA, SF-36 and ABC. Body weight and height were then recorded, followed by static balance. Lastly, STS test and BBS were completed. After Week 8 (Time 2), all participants were scheduled to return once more to the university for the following Time 2 measures: SF-36, ABC, STS, static balance and BBS.

Control Group Protocol

The CG did not participate in the WBV intervention and were encouraged to maintain their current lifestyles. They were also asked to not commence a new exercise regime. CG participants were contacted at four weeks to schedule Time 2 measures when the eight week trial was completed. After baseline and post-tests were completed, they were invited to try the vibration training program.

Intervention Group Protocol

IG sessions were administered at the Victorian Order of Nurses (VON) Healthy Ageing Program located in Cherryhill Village Mall, London, Ontario Canada from April 2010 to August 2010. From September 2010 to November 2010, the intervention took place at the University of Western Ontario Canadian Centre for Activity and Aging, London, Ontario Canada. The setting was an exercise room for both locations.

Prior to the launch of the study, the investigator was trained on the WAVE vibration training machine by WBV researchers. The WAVE is a vertically oscillating platform with frequency settings ranging from 20 – 50 Hz (Figure 1). Amplitude settings are from 2mm (low) or 4mm (high).

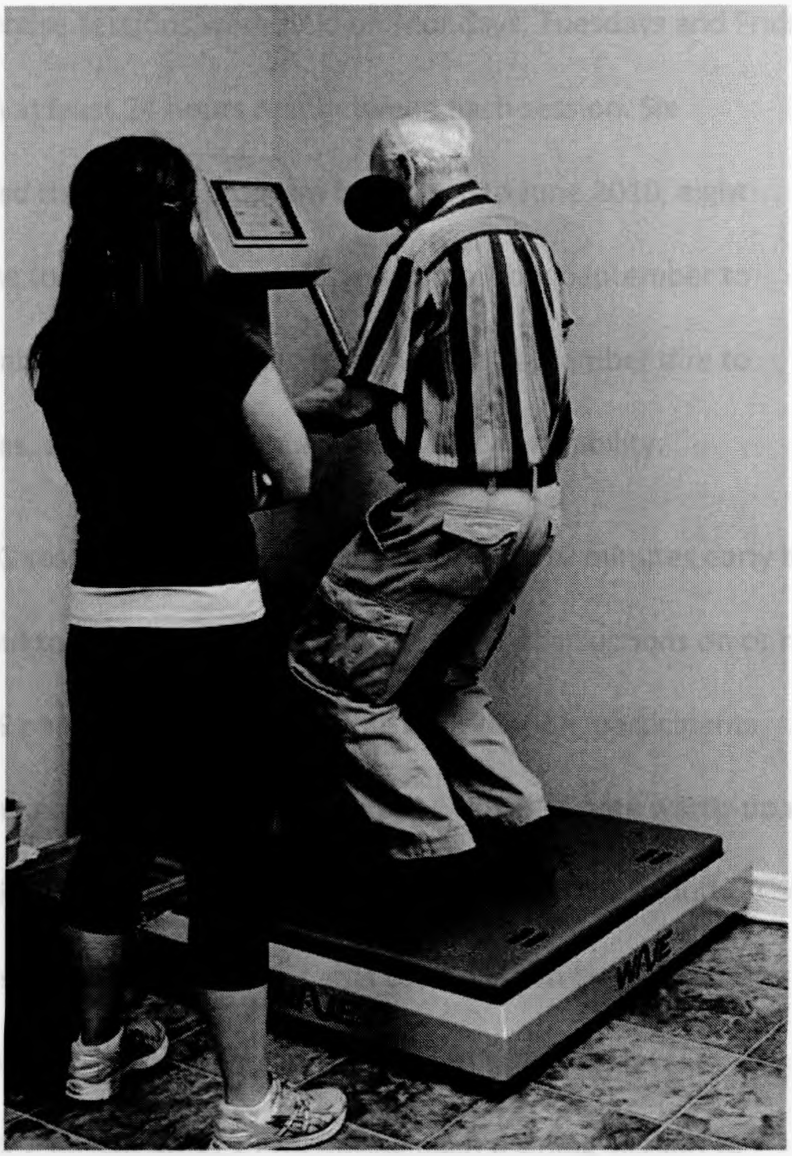

Figure 1. An example of the a vertically oscillating whole-body vibration platform .

WBV participants attended three training sessions per week for eight weeks. An average of three training sessions per week has been found to be a typical protocol in past studies of WBV (Bogaerts et al., 2007; Rees et al., 2008; Runge et al., 2000) and eight weeks of training has demonstrated improvements in strength and balance in community-dwelling older adults (Rees et al., 2008).

Vibration exercise sessions were held on Mondays, Tuesdays and Fridays in the afternoon with at least 24 hours rest between each session. Six participants completed the 8-week program from April to June 2010, eight participants from June to August 2010, and the last ten from September to November 2010. Numbers were staggered from April to September due to recruitment difficulties, as well as equipment and facility availability.

Before each IG session, the investigator arrived 5 to 10 minutes early to prepare the WAVE and to ensure there were no debris or obstructions on or near the platform. Once IG participants arrived for the intervention, participants warmed up by walking around the exercise room. A 5 to 10 minute warm-up and 5 to 10 minute cool down is recommended for the exercising older adult (ACSM, 2010). After each vibration session, participants cooled down by sitting or walking for 5 to 10 minutes. Participants were asked to rate their level of perceived exertion (RPE CR-10; Borg, 1990) during each training session to monitor exercise intensity. Each training session was scheduled for 30 minutes per participant to allow adequate training time for each participant plus a warm up and cool down, and 5 minutes of transition time between sessions.

At the first WBV training session, and prior to the beginning of training on the vibration machine, each participant was introduced to the protocol. Specifically, they were instructed on proper body position, WBV parameters, and the duration of the session. In addition, participants stood on the machine without vibration to practice the correct body position. When the WBV training session began, the investigator instructed each participant to stand on the WBV platform with "soft knees" (e.g. slightly flexed and relaxed). For the first week, participants stood on the vibration platform with knees soft and heels slightly off the platform. This was done to diminish vibration transfer to the upper body and increase dampening in the lower body (Rees et al., 2008). The first IG session consisted of 6 minutes of vibration, for a total session time of 12 minutes (one minute on the platform, one minute off; Rees et al., 2008). Participants were encouraged to take a rest and drink water when needed.

Each consecutive week, an additional minute on the platform was added up to the fifth week, totalling 11 minutes on the platform (Appendix I). At four weeks, participants alternated one-minute sets of dynamic squats with standing for one minute. The alternating sets were incorporated to prevent premature fatigue in the leg muscles, and have been implemented in previous studies (Rees et al., 2008). The trade-off between time spent exercising and intensity was set at a maximum of 11 minutes on the platform to avoid discomfort and to attempt to induce sensorimotor effects from the vibrations (Carlucci et al., 2010). To ensure adequate exercise intensity, rest time off the platform was decreased to 45 seconds at the fourth and fifth week, and decreased to 30 seconds from weeks six to eight. At midpoint during each session, participants were asked to rate their perceived exertion on a scale from 0 (no exertion) to 10 (maximum exertion) (Borg, 1990). Additional information can be found in Appendix J.

Throughout each IG session, the investigator or research assistants observed and recorded any cues from the participant regarding exertion level in field notes. Any residual effects from vibration, such as muscle soreness or tingling in the lower limbs, were also recorded in the field notes.

Data Analysis

A 2x2, Group x Time mixed Analysis of Variance (ANOVA) with repeated measures on the second factor (Time) was used to test for significance between groups, time and interaction for COP summary measures. The Wilcoxon-signed rank and Mann-Whitney U were used to analyze non-parametric data. The level of significance was set at $p < 0.05$. Data were analyzed with the statistics software IBM SPSS Statistics 19.

Results

Changes to Study Protocol

There were several changes to the study protocol after trial commencement. One change was the minimum age of eligibility, which was lowered from 65 to 60 years in order to facilitate the recruitment process. A minimum age of 60 years has been implemented in a previous WBV and balance study (Bogaerts et al., 2007). Another change was two trained volunteer research assistants independently supervised the IG sessions for the last four weeks of the study. In addition, a participant from the IG was removed from the sway analysis due to possible technical error. This participant was included in analysis of all other outcomes (i. e., lower body strength, balance confidence, functional balance and HRQOL). One CG participant was lost-to-follow-up due to disinterest in participation. This participant had completed Time 1 measures, but dropped out of the study prior to completing measures at Time 2. The participant was therefore removed from all analyses. Therefore, 11 participants from the CG and 11 from the IG were analyzed for sway parameters (Figure 2).

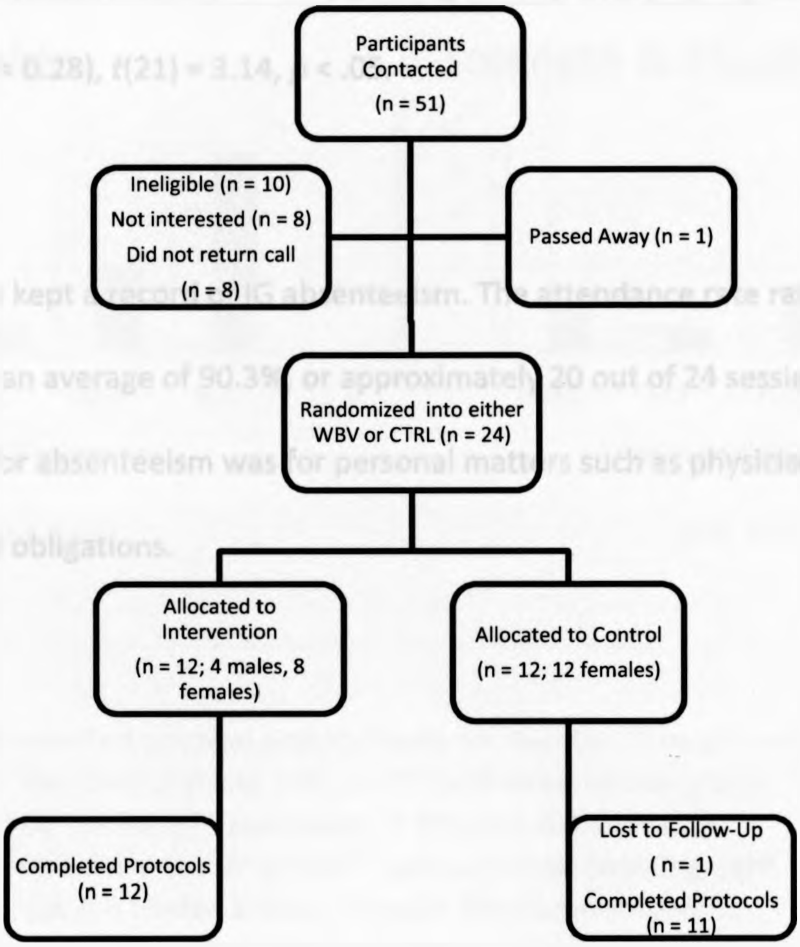

Figure 2. Participant flow in the study.

Participant Demographics

Independent *t*-tests were performed to ensure there were no significant differences between the IG and CG at Time 1. There were no significant differences detected between groups, except for the strength/flexibility RAPA category. This finding indicated that the IG (M = .50, SE = .29) was not as active as the CG (M = 2.0, SE = 0.36), $t(21) = 3.29$, $p < .05$, for strength and flexibility exercises. This was investigated further and the number of participants per RAPA category was tabulated to decipher between the scores for the strength, flexibility, or both activities (Figure 3). It was found that both groups were significantly different for flexibility training activity level (IG; *M* = 0.33, *SE* = 0.22, CG; *M* = 1.45, *SE* = 0.28), $t(21) = 3.14$, $p < .05$.

Completion of Study

The investigator kept a record of IG absenteeism. The attendance rate ranged from 75% - 100%, with an average of 90.3%, or approximately 20 out of 24 sessions. The most frequent reason for absenteeism was for personal matters such as physician appointments or family obligations.

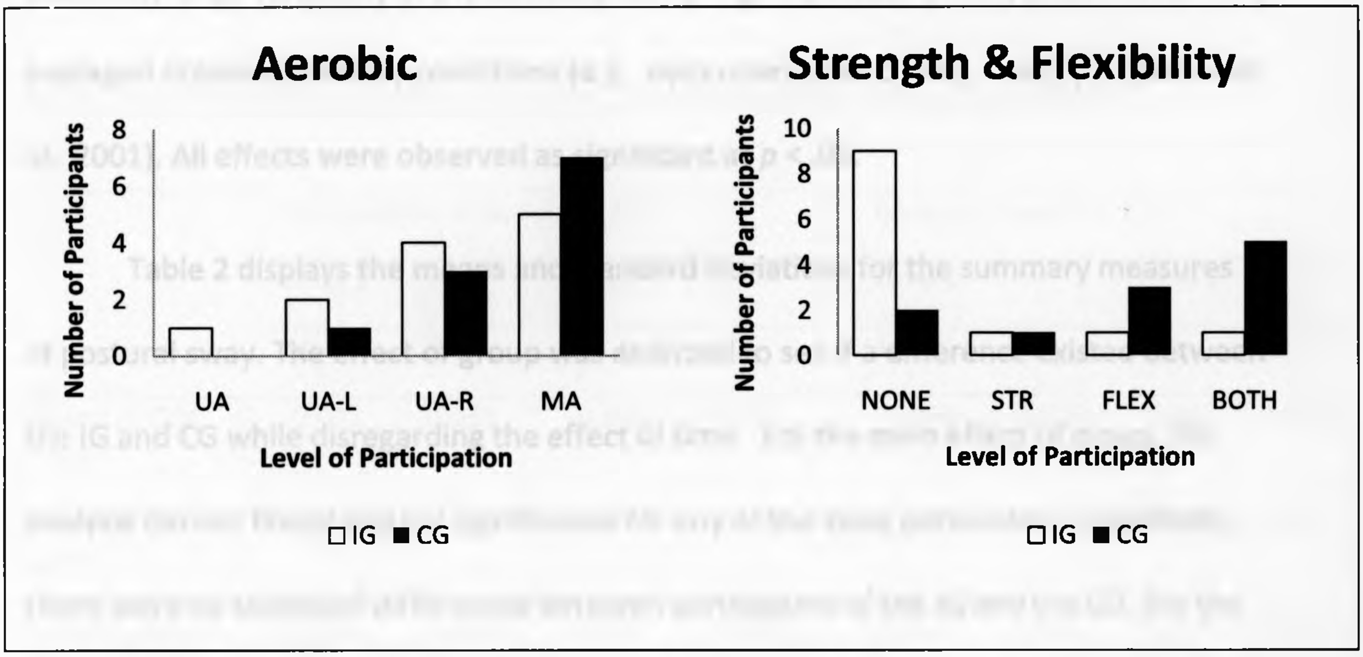

Figure 3. Individual self-reported physical activity levels for Aerobic, Strength and Flexibility categories for the control group (CG; n = 11) and intervention group (IG; n = 12) as measured by the Rapid Assessment of Physical Activity scale (RAPA). UA = Under-active; UA-L = Under-active – Light activities (walking/light housework every week); UA-R = Under-active – Regular (Moderate/vigorous activities for 20-30 minutes such as fast walking or tennis, 3-5 days per week); A = Active (Moderate activity for 30 minutes, more than 5 days per week). Strength and Flexibility Activities: NONE = No strength or flexibility exercises; STR = Strength training (Lifting weights once per week or more); FLEX = Flexibility activities (stretching/yoga once per week or more); BOTH = Performs both strength training and flexibility exercises once per week or more.

Primary Outcomes

Analysis of Variance for Postural Control

To assess for the effects of group, time and the interaction of group x time, a two-way mixed ANOVA with repeated measures on the second factor (Time) was performed for each summary measure of postural sway. Initially, ANOVAs were performed on each sensory condition along with each sway parameter. However, due to extremely large variability in the data and lack of significance, the sway parameters were averaged across all sensory conditions (e.g., eyes open, eyes closed, foam) (Carpenter et al., 2001). All effects were observed as significant at $p < .05$.

Table 2 displays the means and standard deviations for the summary measures of postural sway. The effect of group was analyzed to see if a difference existed between the IG and CG while disregarding the effect of time. For the main effect of group, the analysis did not find statistical significance for any of the sway parameters. Specifically, there were no statistical differences between participants of the IG and the CG. For the effect of time, the data was analyzed to see if there was a difference between Time 1 and time 2 for each group. The analysis revealed no statistical difference for any of the sway parameters from Time 1 and Time 2 (Table 2).

The interaction of group and time was analyzed to see if there is a combined effect of group and time. The interaction effect was non-significant, which indicated there was no difference found between the IG and CG over Time 1 and Time 2. Therefore, the answer to the research question regarding sway was negative: The WBV program did not have an effect on group or time for the IG.

Table 2

Mean Scores and Standard Deviations for Sway Parameters - Time 1 and Time 2.

	Intervention Group (n = 11)				Control Group (n = 11)			
	Time 1		Time 2		Time 1		Time 2	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Mean Lat COP (mm)	-0.041	0.031	-0.042	0.023	-0.044	0.027	-0.042	0.016
Mean AP COP (mm)	0.010	0.012	0.002	0.018	0.013	0.043	0.009	0.025
Lat Var (mm)	5.995	1.833	5.668	1.354	6.340	1.441	6.546	1.602
AP Var (mm)	3.434	2.843	2.536	1.008	3.834	2.879	3.372	1.111
ML Sway (mm)	33.849	10.192	31.880	7.785	35.896	9.272	43.375	19.061
AP Sway (mm)	22.314	23.853	14.940	6.174	22.645	18.174	18.808	5.977
Sway Vel (mm/s)	20.467	8.164	18.779	4.420	21.096	9.270	21.009	6.196
Rad (m)	0.003	0.002	0.003	0.001	0.003	0.002	0.003	0.001

Note. M = Mean; *SD*= Standard Deviation; Mean ML COP=Mean mediolateral Centre of Pressure (mm); Mean AP COP=Mean anterior-posterior Centre of Pressure (mm); ML Var=Lateral Variability (mm); AP Var=Anterior-posterior Variability (mm); ML Sway=Mediolateral Sway Range (mm); AP Sway=Anterior-posterior Sway Range (mm); Rad=Radius enclosing 90% (m).

Table 3

Analysis of Variance for Sway Parameters.

Group Effect	*F*	*p**	Df	Effect Size
Mean Lat COP	0.05	.82	(1,20)	.05
Mean AP COP	0.33	.57	(1,20)	.13
Lat Var	0.94	.34	(1,20)	.21
AP Var	0.70	.41	(1,20)	.18
ML Sway	2.60	.12	(1,20)	.34
AP Sway	0.16	.69	(1,20)	.09
Sway Vel	0.27	.61	(1,20)	.17
Rad	0.15	.71	(1,20)	.09
Time Effect	*F*	*p*	Df	Effect size
Mean Lat COP	0.003	.96	(1,20)	.01
Mean AP COP	0.84	.37	(1,20)	.20
Lat Var	0.07	.79	(1,20)	.06
AP Var	1.58	.22	(1,20)	.27
ML Sway	0.74	.40	(1,20)	.19
AP Sway	1.90	.19	(1,20)	.29
Sway Vel	0.38	.55	(1,20)	.14
Rad	1.60	.22	(1,20)	.27
Interaction	*F*	*p**	Df	Effect size
Mean Lat COP	0.08	.78	(1,20)	.06

Mean AP COP	0.04	.84	(1,20)	.04
Lat Var	1.47	.24	(1,20)	.26
AP Var	0.16	.69	(1,20)	.09
ML Sway	2.18	.15	(1,20)	.31
AP Sway	0.18	.67	(1,20)	.09
Sway Vel	0.31	.59	(1,20)	.12
Rad	0.23	.64	(1,20)	.11

Note. Mean ML COP=Mean mediolateral Centre of Pressure (mm); Mean AP COP=Mean anterior-posterior Centre of Pressure (mm); ML Var=Lateral Variability (mm); AP Var=Anterior-posterior Variability (mm); ML Sway=Mediolateral Sway Range (mm); AP Sway=Anterior-posterior Sway Range (mm); Rad=Radius enclosing 90% (m).

*Significance level set at p < .05

Univariate Effects of Functional Balance, Lower Body Strength, Balance Confidence, Health-related Quality of Life

Tests for normality were conducted on outcome measures, and the results concluded the data for the BBS, ABC, STS and HRQOL violated the assumption of normality. Separate Wilcoxon signed-rank tests were conducted to analyze the main effect of Time for BBS, STS, ABC and HRQOL (Table 4). The Wilcoxon signed-rank test is a non-parametric analysis of two experimental conditions with the same participants, similar to the dependent *t*-test (Field, 2009). To analyze for between-group differences, a Mann-Whitney test was performed on the BBS, STS, ABC and HRQOL. The Mann-Whitney test is the non-parametric version of the independent *t*-test. Non-parametric tests can be used when data violates the assumption of normality. Although non-parametric tests may have an increased Type II error rate, this occurs only if the test is conducted when data are normally distributed (Field, 2009).

When examining the effect of Time for the BBS, there was no statistical significance detected for the CG from Time 1 (*Mdn* = 44.00) and Time 2 (*Mdn* = 50.00), $T = 3$, $p = .15$ (Table 4). There was however a significant difference found for IG between Time 2 (*Mdn* = 50.50) and Time 2 (*Mdn* = 53.00), $T = 4$, $p = .04$. The effect size between Time 1 and Time 2 for the IG indicated a medium effect ($r = -.43$). As the test statistic was based on negative rankings, this indicates that most of the BBS scores were positive, or increased, from Time 1 to Time 2 for the IG. The effect of WBV significantly improved functional balance in the IG, as BBS scores were significantly higher at Time 2 than Time 1. For the between-group analysis, there were no significant group differences found for Time 1 between the IG (*Mdn* = 50.50) and the CG (*Mdn* = 50.00), $U = 51.0$, $z = -.928$, $p = .35$. In addition, at Time 2 there were no differences between the IG (*Mdn* = 53.00) and CG (*Mdn* = 50.00), $U = 42.50$, $z = -1.455$, $p = .15$.

Table 4

Wilcoxon Signed Rank tests of Functional Balance, Muscular Strength, Balance Confidence and subscales of Health-Related Quality of Life

	Intervention group (n = 12)					Control group (n = 11)				
	Median					Median				
	Time 1	Time 2	*p*	*T*	Effect	Time 1	Time 2	*p*	*T*	Effect
BBS (/56)	50.50	53.00	.04*	4	-.43	44.00	50.00	.15	3	-.30
STS (s)	10.75	9.45	.04*	3	-.42	10.80	12.30	.48	4	-.15
ABC (%)	92.50	94.37	.21	4	-.25	93.75	93.00	.66	5	-.09
PF	70.00	72.50	.12	2	-.31	75.00	75.00	.34	4	-.20
RLPH	75.00	100.00	.58	1	-.11	75.00	100.00	.41	1	-.17
RLEH	100.0	100.00	1.00	1	.00	100.00	100.00	.18	2	-.29
ENGY	65.00	72.50	.57	4	-.12	70.00	75.00	.53	3	-.13
EWB	86.00	90.00	.84	4	-.04	80.00	80.00	.44	4	-.16
SF	100.00	100.00	.26	1	-.23	100.00	87.50	.86	3	-.04
Pain	90.00	90.00	.71	1	-.07	87.50	80.00	.78	3	-.06
GH	70.00	80.00	.06	2	-.38	80.00	70.00	.18	3	-.28
CHG	50.00	5.00	.56	1	-.12	50.00	50.00	.19	1	-.28

Note. T = smallest value of summed ranks; BBS= Berg Balance Scale; STS = Sit-to-Stand test; ABC= Activities-Specific Balance Confidence scale; SF-36 subscales – PF = Physical Function; RLPH = Role limitations due to physical health; RLEH = Role limitations due to emotional health; ENGY = Energy/fatigue level; EWB = Emotional wellbeing; SF= Social function; Pain = Amount of bodily pain; GH = General health; CHG = Change in health over the past 12 months.

*Significance level set at p <.05.

For the STS, there was no statistical significance detected for the CG from Time 1 (*Mdn* = 10.80) to Time 2 (*Mdn* = 12.30), $T = 4$, $p = .48$. However, a statistical difference was noted for the IG between Time 1 (*Mdn* = 10.75) to Time 2 (*Mdn* = 9.45), $T = 3$, $p =$

.04, $r = -.42$. The effect size between Time 1 and Time 2 indicated a medium effect from WBV. In fact, the average time to perform five sit-to-stands decreased from Time 1 to Time 2, whereas the CG took longer on average between Time 1 and Time 2. The test statistic was based on the positive ranks for the IG, indicating that for Time 1 to Time 2, the time was significantly lower. There were no group differences found for Time 1 between the IG (*Mdn* = 10.75) and the CG (*Mdn* = 10.80), $U = 65.50$, $z = -.031$, $p = .98$. For Time 2, there were no group differences detected between the IG (*Mdn* = 9.45) and the CG (*Mdn* = 12.30), $U = 48.00$, $z = -1.108$, $p = .29$.

For the ABC, there was no significant difference between Time 1 and Time 2 for either IG or CG. At Time 1, there were no group differences between the IG (*Mdn* = 92.50) and the CG (*Mdn* = 93.75), $U = 62.50$, $z = -.216$, $p = .83$. The between-group findings for Time 2 were also not significantly different between the IG (*Mdn* = 94.37) and the CG (*Mdn* = 93.0), $U = 56.50$, $z = -.343$, $p = .57$.

For the IG the difference for 'General Health' of the SF-36 was close to significant ($p = .06$) for Time. There were no differences in any of the other SF-36 categories within either the IG or CG, indicating that HRQOL did not change over time. In addition, there were no significant differences found for the effect of group for the SF-36. Additionally none of the categories for the SF-36 were significantly different for the IG and CG at Time 1 or Time 2.

Therefore, the answer to the first research question was positive for functional balance as well as lower body strength – the IG improved significantly on the BBS and

STS from Time 1 to Time 2. However, the effect of time was not significant for postural control, balance confidence and health-related quality of life. Furthermore, the effect group was insignificant for all outcome measures. That is, there were no group effects detected from WBV, resulting in a negative answer to the second research question.

Adverse Effects

During the first two weeks of the program, four participants in the IG reported a sensation of "unsteady legs" after completing a WBV session. This residual effect lasted from five to 60 minutes, but was not reported as disrupting the daily activities of participants. Some participants also reported a delayed onset of muscle soreness (DOMS) 24 to 48 hours after a WBV session. However, the DOMS subsided approximately three weeks after the intervention began. In addition, three participants reported minor knee pain randomly during and after WBV sessions. One of these participants attributed the pain to a previous surgery while the other two reported prior overuse injuries. None of those participants felt the need to prematurely finish a WBV set or session.

Discussion

This study assessed whether eight-weeks of WBV training would improve the postural control, functional balance, lower body strength, balance confidence and health-related quality of life in community-dwelling older adults. The results demonstrated that WBV training significantly improved lower body strength and functional balance for the IG from Time 1 to Time 2. Several past studies support that WBV training can improve muscular strength, especially within the older adult population (Bogaerts et al., 2007a; Roelants et al., 2004; Russo et al., 2003). However, eight weeks of WBV training had no effects for postural control, balance confidence and health-related quality of life.

Postural Control

The effects from WBV training are believed to be primarily from the tonic vibration reflex. The mechanical energy from vibration excites the muscle spindles, causing a reflexive muscle contraction. This reflexive contraction is believed to be the reason for reported increases in strength. Moreover, the tonic vibration reflex also affects proprioception, as somatosensory receptors are also excited by vibration. This increase in sensory stimulation, as well as reflexive muscle activity, is thought to result in enhanced postural control. There was no evidence that the postural control of the IG was significantly affected by participating in WBV training for eight weeks. The literature, however, suggests that WBV training may improve postural control. Many of these studies use clinical balance tests to quantify balance. Although clinical tests are useful, they are not necessarily pure measures of balance. For example, the timed up and go test for example is a timed test is affected by muscle strength and/or power (Daubney & Culham, 1999). Few WBV training studies have attempted to separate strength from postural control by using posturography to quantify balance. Of those that have measured posturography, most found that postural control did improve for the WBV group (Bogaerts et al., 2007; Cheung et al., 2007; Rees et al., 2008). The training program of one study was 12-months in duration and incorporated static, dynamic and balancing exercises on a vertical vibration platform (Bogaerts et al., 2007). Thus, a potential reason for the negative results in our study could be that eight weeks of WBV training was not sufficient to achieve postural control modifications. However, one study that evaluated postural control was eight weeks in duration (Rees et al., 2008). The WBV program included standing for the first four weeks, progressing to dynamic lower body exercises. A tilting vibration platform was used (i.e., tilts left to right like a teeter-totter). Rees et al. found that force variability of the WBV group improved compared to an exercise group. In addition, further support was found for postural control in a 3-month standing-only WBV training program (Cheung et al., 2007). Cheung et al., (2007) found that after only three minutes per session, balance improved in community-dwelling older adults. The Limits of Stability was used to quantify postural control. The test used a force plate to trace the displacement of the centre of gravity when study participants swayed in eight targeted directions. The WBV group saw significant gains for balance compared to the control group. One reason why the studies by Rees et al. (2008) and Cheung et al. (2007) were successful might be the choice of vibrating platform. It has been noted that tilting platforms produce stronger gravitational forces than vertical vibrating platforms (Pel et al., 2009). In addition, rotating platforms induce mediolateral perturbations, creating oscillations at the spine and hips (Pel et al., 2009), providing the neuromuscular system with a different stimulus than vertical vibrating platforms. Therefore, perhaps for protocols that are eight to 12 weeks in duration, it might be more appropriate to use a platform that produces mediolateral rotating vibrations.

Another possible reason for the negative results in the present study may be that the postural control measure was not challenging enough to detect balance modifications. If the muscular strength threshold exceeds the postural disturbance, it is difficult to obtain a "true" balance reading. For example, Lin & Woollacott (2005) found that older adults in their sample were able to recover balance without difficulty when exposed to medium-sized postural perturbations. It could be that our force plate balance protocol was not difficult enough and did not exceed the muscular strength threshold of our sample. Future studies should consider decreasing the base of support for posturography tests, such as tandem stance or standing on one leg, as seen in Rees et al., (2008). In addition, participants were relatively high functioning; they were moderately active and were considered "healthy". This could be another reason why no differences were detected for time or group. High functioning older adults may not be substantially affected from WBV training compared to low functioning groups (Merriman & Jackson, 2009).

Functional Balance

The Berg Balance Scale was incorporated to examine functional balance in older adults. It is a widely-used clinical tool and is the best single predictor of fall risk (Shumway-Cook et al., 1997). In the present study, the IG improved significantly from Time 1 to Time 2 on the Berg Balance Scale, and there was no change in the CG scores. The Berg Balance Scale assesses balance while performing functional tasks such as sitting to standing, transfers, and timed step-ups on a stool. The Berg Balance Scale may be related to lower body strength (Daubney & Culham, 1999). Since there was no statistical difference found for postural control, it is difficult to decipher whether improvements on the Berg Balance Scale in the present study are the result of balance improvements or lower body strength.

Lower Body Strength

There is strong support in the literature that WBV training improves muscular strength and power in older adults (Merriman & Jackson, 2009; Roelants et al., 2004; Russo et al., 2003; Verschueren et al., 2004). Muscular strength is a critical component of an older adult's daily routine, as loss of strength can lead to frailty and disability (Shumway-Cook & Woollacott, 2001). It is essential, therefore, that older adults perform strengthening exercises, as recommended by Canada's Physical Activity Guide (Canadian Society for Exercise Physiology, 2011). In the present study, the Sit-to-Stand time of the IG improved significantly from Time 1 to Time 2, though there was no change for the CG. The Sit-to-Stand is a quick and effective indirect measure of quadriceps strength (Lord, Murray, Chapman, Munro & Tiedemann, 2002). Our results coincide with other WBV studies that demonstrated improvements in clinical tests that are affected by muscular strength and power (Bogaerts et al., 2007a; Roelants et al., 2004). The reflexive muscle contraction stimulated by WBV, known as the tonic vibration reflex (TVR), is thought to be responsible for these changes (Cardinale & Bosco, 2003).

Health-related Quality of Life

One goal of the present study was to verify whether the health-related quality of life of community-dwelling older adults was affected by the WBV intervention. The connection between perceived health and quality of life of older adults is well-established (Blane, Netuveli & Montgomery, 2008). Our results demonstrated there were no statistical significance found between groups or over time. The only previous WBV study to investigate health-related quality of life found it significantly increased after six weeks of training (Bruyere et al., 2005). However, the participants were long-term care residents who reported relatively low health-related quality of life at Time 1. For example, the Time 1 scores ranged from 27.3 to 63.3 points. On the other hand, the scores from the present study ranged from 64.6 to 85.4 points at Time 1. This lack of significance in our study could be due to initial scores on the SF-36, indicating a relatively high health-related quality of life at Time 1. It may be worth investigating if a relationship exists between WBV training and older adults with low health-related quality of life. Lower functioning older adults tend to benefit from WBV exercise more than higher functioning older adults (Merriman & Jackson, 2009).

Balance Confidence

To the knowledge of the author, this study is the first to explore the possible relationship between WBV and balance confidence. Past studies have demonstrated that balance confidence has improved from traditional exercise programs (Zijlstra et al., 2007); therefore it is plausible that WBV training may also affect balance confidence. In the present study there were no significant differences detected for group and time for balance confidence. However, the IG marginally improved in comparison to the CG. The IG scored an average of 82.2% ±25.7 at Time 1, which improved to 86.6% ±14.8 at Time 2. The CG scored 83.3%±23.9 at Time 1, and 84.4%±18.8 at Time 2. In a study that compared the ABC of fallers to non-fallers, the non-fallers had an average ABC score of 85% (Lajoie & Gallagher, 2004). The fallers had a significantly lower score of 48%, which indicates low functional mobility (Myers et al., 1998). A score of 80% or greater indicates high function and mobility, making it unlikely that balance confidence will increase from a balance training program (Myers et al., 1998). The majority of the participants in the present study were at a low fall risk, and none were at a severe fall risk according to the Berg Balance Scale. This ceiling effect could be the reason for the lack of responsiveness to the program in the present study (Talley et al., 2008). An ABC score of 70% or less is more likely to be responsive to a balance confidence program (Myers et al., 1998). It would be interesting to evaluate the effects of WBV training on a low balance confidence group (less than 70% ABC score). This topic warrants further investigation, as fear of falling can be detrimental to mobility and increase fall risk (Powell & Myers, 1995).

Tolerance for WBV Training

Most WBV training studies achieve an excellent adherence rate and report minor side effects (if any). Adverse events in past studies include DOMS (Cheung et al., 2007), mild knee pain (Roelants et al., 2004) and temporary itching (Bruyere et al., 2005). However, the lack of standard safety protocols (Soiza, 2010) and vibration exposure to the head (Brooke-Wavell & Mansfield, 2009) have caused some concern about whether WBV training is safe and tolerable for older adults. Therefore it is important to establish adequate and safe training protocols for older adults. Conversely, others have touted WBV as a safe, efficient and effective exercise modality for older adults (Merriman & Jackson, 2009). Obtaining constant feedback from participants can help to ensure tolerance and safety. The investigator recorded field notes and participant comments at every WBV training session.

Many participants enjoyed the program and it was well-tolerated. One participant appeared to benefit the most from the intervention. The peers of this participant remarked he was “moving around better”. At Time 2, the participant improved by 11 points on the Berg Balance Scale. A 1-point change on the Berg Balance Scale can lead to a 6 – 8% decrease in risk of a fall (Shumway-Cook et al., 1997). In addition, the ABC score of the individual improved from 14.5% to 61.25% - an increase of 46.75%. The effects of targeting WBV training to community-dwelling older adults with a higher fall risk and low balance confidence warrants further investigation.

Several of the participants felt the vibrations had a “soothing sensation”, similar to a leg massage. In addition, some participants commented they were sad the trial was ending and wished to continue the training. Several of the sedentary participants commented that their mobility improved and attributed the improvement to the WBV training. Numerous WBV studies report improvements in mobility and gait after six to eight weeks of training (Bautmans et al., 2005; Bruyere et al., 2005; Furness et al., 2010). Another participant felt the WBV training improved her health immensely and purchased a WBV platform for personal use. One of the higher functioning participants reported the program was boring. Another high functioning participant did not enjoy performing the squat exercises due to increased muscular tension. Adverse events reported by participants included muscle soreness and mild knee pain, which coincides with other studies (Bruyere et al., 2005; Cheung et al., 2007; Roelants et al., 2004). Overall, the 8-week WBV program in this study was very well tolerated by participants. This program may be more appropriate for sedentary, lower functioning older adults who may benefit more from WBV training than higher functioning older adults (Merriman & Jackson, 2009).

Limitations

Low power, high variability within and between groups and choice of tests are some of the limitations in this study. Statistical power is the ability of a test to detect an effect (Field, 2009). The inability to recruit participants, leading to a smaller than desired sample size, diminished the experimental power (Agresti & Finlay, 2009). In addition, the investigator and participants were not blinded, which could lead to potential bias.

Moreover, the Berg Balance Scale is a subjective measure, where an assessor rates the participant on functional tasks. Due to the Berg Balance Scale's subjective nature, it could also lead to potential bias.

The large variability for several outcome measures, such as the ABC, various health-related quality of life categories and postural control at Time 1 and Time 2 may also be another limitation. Since the present study was exploratory in nature, volunteers that met study criteria and resided in the community were accepted. This could increase the level of unsystematic variation within the sample of the present study, thus making it difficult to detect an effect from the WBV training. The variation between participants could be a result of the sample, which varied in age as well as function. In an attempt to alleviate the effect of the skewed postural control data, the sensory conditions for each summary measure were compiled into average sway values. This could have over-estimated or under-estimated values for sway, as certain sensory-altered conditions can induce greater sway than others (Horak et al., 1989). An additional potential limitation could be the duration of the training program. Bogaerts et al. (2007) demonstrated that 12 months of WBV training on a vertical vibration platform is associated with a decreased fall risk in older adults. Therefore this program may not have been long enough to modify postural control in older adults.

Recommendations for Future Trials

Due to the lack of evidence in this study for postural control, it may be beneficial to gradually implement additional balance components to the intervention. For example, standing on one leg with eyes closed would challenge balance control (Bogaerts et al., 2007). In their WBV training study, Bogaerts et al. (2007) combined static and dynamic lower body exercises on the vibration platform, which eventually progressed to one-legged squats with eyes closed. It may also be beneficial to conduct a longer duration study, such as the 12-month study conducted by Bogaerts et al. (2007) where improved balance control was associated with the WBV training group.

To the knowledge of the author, this is the first study to investigate balance confidence in a WBV training study. The psychological aspect of falling can negatively impact function and quality of life (Liu-Ambrose et al., 2006; Suzuki et al., 2002). It is worth examining the potential paradigm of fear of falling and WBV training. Balance confidence marginally increased for the IG, however this interpretation is cautioned as it was not statistically significant. Past studies have demonstrated that balance performance on the Berg Balance Scale is strongly associated with ABC scores (Hatch, Gill-Body & Portney, 2003). In the present study, Berg Balance Scale scores significantly improved from Time 1 to Time 2 for the IG. Therefore, older adults at a higher risk of fall (less than 70% ABC score; Myers et al., 1998) may be an appropriate population for future studies on WBV training and balance confidence. This population is more likely to achieve balance confidence gains from a balance training program (Myers et al., 1998).

Several studies have suggested that WBV training is a valuable tool to improve balance and strength in older adults (Bogaerts et al., 2007a; Bruyere et al., 2005; Rees et al., 2008; von Stengler et al., 2010). Bogaerts et al. (2007) demonstrated that WBV training was associated with a lower fall risk. The potential of WBV training to affect balance confidence is in need of further investigation, as the implications could be substantial from a falls prevention perspective.

Other recommendations for future studies include a larger sample size to improve power. In addition, the blinding of participants and research assistants would decrease potential bias. Stratified sampling of participants into groups with specific characteristics, such as fall risk, may help decrease sampling error (Babbie & Benaquisto, 2002). Incorporating these factors would improve the scientific rigor of the study.

Conclusion

There is robust evidence that WBV training can improve leg strength in older adults. It is also theorized that a possible neuromuscular adaptation may occur, which could translate into improved postural control (Bogaerts et al., 2007; Rees et al., 2008). Functional balance and strength improvements demonstrate the benefits of WBV training (Bautmans et al., 2005; Bruyere et al., 2005). However, evidence for neuromuscular adaptations separate from strength was not found in the present study; that is, there were no significant WBV training effects for postural control. In addition, balance confidence and health-related quality of life did not significantly improve after eight weeks of WBV training.

The lack of significance for postural control in our study could mean that vertically oscillating vibration stimulus is an insufficient stimulus to improve balance in older adults. It could also indicate that our WBV intervention and balance protocol did not sufficiently challenge the balance of our sample. It is postulated the significant improvements in functional balance were the result of increased strength, as the BBS is related to lower body strength (Daubney & Culham, 1999). Regardless of the null results for postural control, the potential of WBV as a balance training mechanism should not be disregarded.

It is acknowledged that WBV should not replace a regular exercise routine. Consistent aerobic, muscular strength, balance and flexibility exercises are important for autonomy and quality of life in advancing age (CSEP, 2011). However, WBV training could complement such a program or provide a starting point for frailer older adults who may be unable to exercise in a more traditional manner.

Future recommendations include incorporating balance exercises for WBV training and choosing a more challenging postural sway assessment. Factors to increase the scientific rigor of future studies should be implemented. In addition, the WBV training program in the current study may be more appropriate for lower functioning older adults at a higher fall risk; however this warrants further investigation. Areas worthy of future WBV training research include fear of falling, quality of life, sarcopenia and postural control.

The WBV and older adult literature continues to grow as the use of WBV for becomes increasingly popular in the media, exercise clubs and research laboratories. It is evident that WBV can be an effective and efficient method of strength training, especially for low-functioning older adults (Merriman & Jackson, 2009). The strength and power improvements from WBV training have been hypothesized to be the result of muscle fibre response to the tonic vibration reflex (Bogaerts et al., 2007a). The potential of WBV to reduce or prevent sarcopenia could have significant clinical application, as it is a factor in age-related functional decline and fall risk (Robinson et al., 2004). However, the optimal dosage and prescription of WBV training remains unknown (Merriman & Jackson, 2009). Standardized WBV training protocols are required to establish safe and effective training guidelines for older adults.

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Appendix A

The Rapid Assessment of Physical Activity tool (RAPA; Topolski et al., 2006)

Rapid Assessment of Physical Activity

Physical Activities are activities where you move and increase your heart rate above its resting rate, whether you do them for pleasure, work, or transportation.

The following questions ask about the amount and intensity of physical activity you usually do. The intensity of the activity is related to the amount of energy you use to do these activities.

Examples of physical activity intensity levels:

Light activities · your heart beats slightly faster than normal · you can talk and sing	
Moderate activities · your heart beats faster than normal · you can talk but not sing	
Vigorous activities · your heart rate increases a lot · you can't talk or your talking is broken up by large breaths	

How physically active are you? *(Check one answer on each line)*

	Does this accurately describe you?	
I rarely or never do any physical activities	Yes ☐	No ☐
I do some **light** or **moderate** physical activities, but not every week.	Yes ☐	No ☐
I do some **light** physical activity every week.	Yes ☐	No ☐
I do **moderate** physical activities every week, but less than 30 minutes a day or 5 days a week.	Yes ☐	No ☐
I do **vigorous** physical activities every week, but less than 20 minutes a day or 3 days a week.	Yes ☐	No ☐
I do 30 minutes or more a day of **moderate** physical activities, 5 or more days a week.	Yes ☐	No ☐
I do 20 minutes or more a day of **vigorous** physical activities, 3 or more days a week.	Yes ☐	No ☐
I do activities to increase **muscle strength**, such as lifting weights or calisthenics, once a week or more.	Yes ☐	No ☐
I do activities to improve **flexibility**, such as stretching or yoga, once a week or more.	Yes ☐	No ☐

ID # ____________________

Today's Date ____________________

Scoring Instructions

RAPA 1: Aerobic

To score, choose the question with the highest score with an affirmative response. Any number less than 6 is suboptimal.

For scoring or summarizing categorically:

Score as sedentary:

1. I rarely or never do any physical activities

Score as under-active:

2. I do some light or moderate physical activities, but not every week.

Score as under-active regular – light activities:

3. I do some light physical activity every week

Score as under-active regular:

4. I do moderate physical activities every week, but less than 30 minutes a day or 5 days a week
5. I do vigorous physical activities every week, but less than 20 minutes a day or 3 days a week

Score as active:

6. I do 30 minutes or more a day of moderate physical activities, 5 or more days a week
7. I do 20 minutes or more a day of vigorous physical activities, 3 or more days a week.

RAPA 2: Strength & Flexibility

I do activities to increase muscle strength, such as lifting weights or calisthenics, once a week or more. (1)

I do activities to improve flexibility, such as stretching or yoga, once a week or more. (2)

Both. (3)

None (0)

Appendix B

University of Western Ontario Health Sciences Research Ethics Board approval form

Western

Office of Research Ethics

The University of Western Ontario
Room 4180 Support Services Building, London, ON, Canada N6A 5C1
Telephone: (519) 661-3036 Fax: (519) 850-2466 Email: ethics@uwo.ca
Website: www.uwo.ca/research/ethics

Use of Human Subjects - Ethics Approval Notice

Principal Investigator: Dr. A.W. Salmoni
Review Level: Expedited
Review Number: 15923E
Revision Number: 2
Review Date: August 20, 2010
Approved Local # of Participants: 35
Protocol Title: The effects of whole-body vibration on exercise self-efficacy in healthy older adults
Department and Institution: Kinesiology, University of Western Ontario
Sponsor:
Ethics Approval Date: August 20, 2010
Expiry Date: March 31, 2011
Documents Reviewed and Approved: Revised study end date.
Documents Received for Information:

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the HSREB except when necessary to eliminate immediate hazards to the subject or when the change(s) involve only logistical or administrative aspects of the study (e.g. change of monitor, telephone number). Expedited review of minor change(s) in ongoing studies will be considered. Subjects must receive a copy of the signed information/consent documentation.

Investigators must promptly also report to the HSREB:

a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) all adverse and unexpected experiences or events that are both serious and unexpected;
c) new information that may adversely affect the safety of the subjects or the conduct of the study.

If these changes/adverse events require a change to the information/consent documentation, and/or recruitment advertisement, the newly revised information/consent documentation, and/or advertisement, must be submitted to this office for approval.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

[redacted]

Chair of HSREB: Dr. Joseph Gilbert
FDA Ref. #: IRB 00000940

Ethics Officer to Contact for Further Information			
☐ Janice Sutherland (jsutherl@uwo.ca)	☐ Elizabeth Wambolt (ewambolt@uwo.ca)	☑ Grace Kelly (grace.kelly@uwo.ca)	☐ Denise Grafton (dgrafton@uwo.ca)

This is an official document. Please retain the original in your files. cc: ORE File

UWO HSREB Ethics Approval - Revision
V.2008-07-01 (rptApprovalNoticeHSREB_REV) 15923E Page 1 of 1

Appendix C

Poster advertised to recruit participants

We need your help for our study!

If you:

- are over the age of 65 and
- do not exercise at a high intensity for more than 2 hours per week, and
- are interested in potentially improving your balance, muscular strength, balance confidence and quality of life...

We are looking for participants for a study at the University of Western Ontario on the improvement of balance confidence and health-related quality of life in older adults.

Balance confidence, good balance and muscular strength may contribute to a better quality of life and a decreased fall risk in older adults. This study focuses on a safe, new technique that may possibly improve these important factors.

- Participants will attend 15-20 minute sessions 3 times per week for 8 weeks at the **VON Healthy Ageing Centre in Cherryhill Mall**
- Participation in this study requires minimal exercise (standing on a platform that delivers vibration at a therapeutic level, intermittent with chair rises at four weeks).

If you are interested in participating in this study, please contact:

Lyndsay F, Graduate Student
University of Western Ontario
Phone: XXX-XXX-XXXX

Vibration Study XXX- XXXX	Vibration Study XXX- XXXX	Vibration Study XXX- XXXX	Vibration Study XXX- XXXX	Vibration Study XXX- XXXX	Vibration Study XXX- XXXX	Vibration Study XXX- XXXX	Vibration Study XXX- XXXX	Vibration Study XXX- XXXX

Appendix D

COP sway parameter descriptions (Doyle et al., 2007; Prieto et al., 1996)

Parameter	Description
Mean ML COP (mm)	Mean of COP in ML direction (Prieto et al., 1996)
Mean AP COP (mm)	Mean of COP in AP direction (Prieto et al., 1996)
ML sway variability (mm)	Standard deviation of the COP in the ML direction (Doyle et al., 2007)
AP sway variability (mm)	Standard deviation of the COP in the AP direction (Doyle et al., 2007)
ML Sway Range (mm)	Difference between the smallest and the largest value in the ML direction (Prieto et al., 1996)
AP Sway Range (mm)	Difference between the smallest and the largest value in the AP direction (Prieto et al., 1996)
Sway Velocity (mm/s)	Average velocity of COP (total distance traveled divided by time of the trial) (Doyle et al., 2007)
Radius enclosing 90% (m)	Circle enclosing 90% of the distances from the mean COP (Prieto et al., 1996)

Appendix E

Sensory-altered balance conditions completed at Time 1 and Time 2

Condition*	Sensory Systems Altered	Sensory System(s) Not Altered
1: EO, NN,NoF	None	All
2: EO, NN, F	Somatosensory	Visual Vestibular
3: EO, NE, NoF	Vestibular	Visual Somatosensory
4: EO, NE, F	Somatosensory Vestibular	Visual
5: EC, NN, NoF	Visual	Somatosensory Vestibular
6: EC, NE, NoF	Visual Vestibular	Somatosensory
7: EC, NN, F	Visual Somatosensory	Vestibular
8: EC, NE, F	All	None

*EC = Eyes Closed; EO= Eyes Open; NE= Neck Extended; NN=Neck Neutral; F=Foam on force plate; NoF=No foam on force plate

Appendix F1

The Activity-specific Balance Confidence Scale (ABC; Powell & Myers, 1995)

The Activities-specific Balance Confidence (ABC) Scale

For <u>each</u> of the following activities, please indicate your level of self-confidence by choosing a corresponding number from the following rating scale:

0%	10	20	30	40	50	60	70	80	90	100%
No Confidence										Completely Confident

"How confident are you that you can maintain your balance and remain steady when you....

1. walk around the house? _____%
2. walk up or down stairs?_____%
3. bend over and pick up a slipper from the front of a closet floor? _____%
4. reach for a small can off a shelf at eye level? _____%
5. stand on your tip toes and reach for something above your head? _____%
6. stand on a chair and reach for something?_____%
7. sweep the floor?_____%
8. walk outside the house to a car parked in the driveway?_____%
9. get into or out of a car?_____%
10. walk across a parking lot to the mall?_____%
11. walk up or down a ramp?_____%
12. walk in a crowded mall where people rapidly walk past you?_____%
13. are bumped into by people as you walk through the mall?_____%
14. step onto or off of an escalator while holding onto a railing?_____%
15. step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing?_____%
16. walk outside on icy sidewalks?_____%

Appendix F2

The Medical Outcome Survey Short-form 36 (SF-36; RAND Corporation, 2009)

SF-36 QUESTIONNAIRE
(1992 – Medical Outcomes Trust)

Patient Name: ______________________ **Date:** ______________

1. In general, would you say your health is: (circle one)

Excellent Very good Good Fair Poor

2. Compared to one year ago, how would you rate your health in general now? (circle one)

Much better now than one year ago

Somewhat better now than one year ago

About the same as one year ago

Somewhat worse than one year ago

Much worse than one year ago.

3. The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much? (Mark each answer with an X)

ACTIVITIES	Yes, Limited A Lot	Yes, Limited A Little	No, Not Limited At All
a. Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports			
b. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf			
c. Lifting or carrying groceries			
d. Climbing several flights of stairs			
e. Climbing one flight of stairs			
f. Bending, kneeling or stooping			
g. Walking more than a mile			
h. Walking several blocks			
i. Walking one block			
j. Bathing or dressing yourself			

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health? (Mark each answer with an X)

	YES	NO
a. Cut down on the amount of time you spent on work or other activities		
b. Accomplished less than you would like		
c. Were limited in the kind of work or other activities		
d. Had difficulty performing the work or other activities (for example, it took extra effort)		

5. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)? (Mark each answer with an X)

	YES	NO
a. Cut down the amount of time you spent on work or other activities		
b. Accomplished less than you would like		
c. Didn't do work or other activities as carefully as usual		

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors or groups? (circle one)

Not at all Slightly Moderately Quite a bit Extremely

7. How much bodily pain have you had during the past 4 weeks? (circle one)

None Very mild Mild Moderate Severe Very severe

8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

Not at all A little bit Moderately Quite a bit Extremely

9. These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past 4 weeks – (Mark each answer with an X)

	All of the Time	Most of the Time	A Good Bit of the Time	Some of the Time	A Little of the Time	None of the Time
a. Did you feel full of pep?						
b. Have you been a very nervous person?						
c. Have you felt so down in the dumps that nothing could cheer you up?						
d. Have you felt calm and peaceful?						
e. Did you have a lot of energy?						
f. Have you felt downhearted and blue?						
g. Did you feel worn out?						
h. Have you been a happy person?						
i. Did you feel tired?						

10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)? (circle one)

All of the time Most of the time Some of the time A little of the time None of the time

11. How TRUE or FALSE is each of the following statements for you?

	Definitely True	Mostly True	Don't Know	Mostly False	Definitely False
a. I seem to get sick a little easier than other people					
b. I am as healthy as anybody I know					
c. I expect my health to get worse					
d. My health is excellent					

Appendix F3

The Berg Balance Scale (Berg, Wood-Dauphinee, Williams & Gayton, 1989)

Berg Balance Scale continued...

REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: [illegible]
( ) 4 [illegible]
( ) 3 [illegible]
( ) 2 [illegible]
( ) 1 [illegible]
( ) 0 [illegible]

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: [illegible]
( ) 4 [illegible]
( ) 3 [illegible]
( ) 2 [illegible]
( ) 1 [illegible]
( ) 0 [illegible]

TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
INSTRUCTIONS: [illegible]
( ) 4 [illegible]
( ) 3 [illegible]
( ) 2 [illegible]
( ) 1 [illegible]
( ) 0 [illegible]

TURN 360 DEGREES
INSTRUCTIONS: [illegible]
( ) 4 [illegible]
( ) 3 [illegible]
( ) 2 [illegible]
( ) 1 [illegible]
( ) 0 [illegible]

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: [illegible]
( ) 4 [illegible]
( ) 3 [illegible]
( ) 2 [illegible]
( ) 1 [illegible]
( ) 0 [illegible]

STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) [illegible]
( ) 4 [illegible]
( ) 3 [illegible]
( ) 2 [illegible]
( ) 1 [illegible]
( ) 0 [illegible]

STANDING ON ONE LEG
INSTRUCTIONS: [illegible]
( ) 4 [illegible]
( ) 3 [illegible]
( ) 2 [illegible]
( ) 1 [illegible]
( ) 0 [illegible]

( ) TOTAL SCORE (Maximum = 56)

Berg Balance Scale

SITTING TO STANDING
INSTRUCTIONS: Please stand up. Try not to use your hand for support.
( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or stabilize
( ) 0 needs moderate or maximal assist to stand

STANDING UNSUPPORTED
INSTRUCTIONS: Please stand for two minutes without holding on.
( ) 4 able to stand safely for 2 minutes
( ) 3 able to stand 2 minutes with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL
INSTRUCTIONS: Please sit with arms folded for 2 minutes.
( ) 4 able to sit safely and securely for 2 minutes
( ) 3 able to sit 2 minutes under supervision
( ) 2 able to able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

STANDING TO SITTING
INSTRUCTIONS: Please sit down.
( ) 4 sits safely with minimal use of hands
( ) 3 controls descent by using hands
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but has uncontrolled descent
( ) 0 needs assist to sit

TRANSFERS
INSTRUCTIONS: Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.
( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cuing and/or supervision
( ) 1 needs one person to assist
( ) 0 needs two people to assist or supervise to be safe

STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding on.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds

Appendix G

Letter of Information presented to study participants at Time 1

Western

The Effects of Whole Body Vibration on Balance Confidence and Health-Related Quality of Life in Healthy Older Adults

LETTER OF INFORMATION

Introduction
My name is Lyndsay Foisey and I am Masters student at the Faculty of Health Sciences at The University of Western Ontario. My supervisor, Dr. Alan Salmoni, and I are currently conducting research into vibration, balance, strength and balance confidence and would like to invite you to participate in this study. Dr. Alan Salmoni's contact information is as follows: 519-661-2111 ext 83541 or asalmoni@uwo.ca.

Purpose of the study
The aims of this study are to see if whole body vibration training has any effect on 1) balance and lower body strength and 2) balance confidence and health-related quality of life.

If you agree to participate
Approximately 35 participants will be divided randomly (i.e. like the flip of a coin) into two groups (vibration training group or a control group).

It is important that you are not currently taking part in a prescribed exercise routine. Participation in this study is not recommended if you have any of the following conditions: Uncontrolled diabetes, epilepsy, gall stones, kidney stones, acute inflammations, joint problems, cardiovascular diseases, joint implants, recent thrombosis, back problems such as hernia, tumours, recent operative wounds, intense migraines, neuromuscular or neurodegenerative diseases, strokes, or had a recent bypass or stent. It is strongly recommended to seek medical clearance before starting any exercise program.

Vibration Training Group:
You will be asked to attend vibration training sessions three times per week for 8 weeks at the Healthy Ageing Centre located in Cherryhill Mall (301 Oxford Street West London, ON) or the Canadian Centre for Activity and Aging (1490 Richmond Street, London, ON). A vibration training session

1

consists of standing on a vibrating platform with and chair rises while holding on to the handrails for a maximum of 15 minutes (there will be intermittent rest sessions off the platform of 30 - 60 seconds).

Control Group:
If you are selected for the control condition, you will not be required to take part in the vibration training. During your participation in this study, it is also important to not start an exercise program (i.e. weight lifting, aerobics, walking program, etc.).

Both vibration and control groups will be asked to complete a questionnaire regarding balance confidence and health-related quality of life (which will take approximately 30 minutes) at the beginning and end of the study at Rm 2125 at the Biomechanics Lab, Thames Hall, University of Western Ontario (London ON). There is parking available at the Weldon Visitor Parking Lot. Participants will be reimbursed for parking or taxi fare. Both groups will be asked to participate in several balance measurements (postural sway on a force plate in eight conditions - eyes open/closed, standing on foam with eyes open/closed, standing with neck extended with eyes open/closed, standing with neck extended on foam with eyes open/closed). These measures will take approximately 60 minutes to measure. To ensure participant safety, there will be spotters on both sides of the participant. Muscular strength will be measured by performing a chair rise test. Testing sessions before and after the vibration training will take approximately 1.5 hours total for each time.

Confidentiality
The information collected will be used for research purposes only, and neither your name nor information which could identify you will be used in any publication or presentation of the study results. All information collected for the study will be kept confidential. All data will be stored on a password-protected, encrypted file on a computer in the Aging & Ergonomics Laboratory. Participant confidentiality will be protected by assigning a subject number (i.e. S01). Once data is complete, any files containing personal information will be destroyed. Only data with subject numbers will be retained. If you wish to receive results of this study, please provide your contact information on a separate piece of paper.

Representatives of the University of Western Ontario Health Sciences Research Ethics Board may contact you or require access to your study – related records to monitor the conduct of the research.

Risks & Benefits
Benefits from participating in this study may include improved balance and strength and balance confidence, which may lead to a decrease in fall risk.

The risk involved in this study is the possibility of muscle fatigue or soreness. Whole-body vibration is a method of skeletal muscle training which may cause similar muscle fatigue or soreness to that of a standard weight lifting session.

Voluntary Participation
Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time.

Questions
If you have any questions about the conduct of this study or your rights as a research participant you may contact the Manager, Office of Research Ethics, The University of Western Ontario at 519-661-3036 or ethics@uwo.ca. If you have any questions about this study, please contact Lyndsay Foisey at [redacted] or [redacted] or Dr. Alan Salmoni at [redacted] ext [redacted] [redacted]

This letter is yours to keep for future reference.

____

Lyndsay Foisey, BA (Hon), CK
MSc Student
Department of Health & Rehabilitation Sciences (Health & Aging)
Faculty of Health Sciences, The University of Western Ontario
[redacted]

Appendix H

Demographic questionnaire completed at Time 1 by participants

DEMOGRAPHIC QUESTIONNAIRE (to be completed by the participant or researcher). All of your answers will be kept CONFIDENTIAL.

PARTICIPANT CODE # _______

1. **How old are you? _______ years**
2. **Are you (circle one): MALE FEMALE**
3. **What is your ethnic background (circle one):**
   CAUCASIAN
   AFRICAN AMERICAN
   ASIAN
   FIRST NATIONS
   OTHER
4. **What is your marital status (circle one)?**
   Single Married Widower/Widowed Common Law
5. **What is your yearly income (circle one)?**
   <$10,000 $10,000 - $25,000 $26,000 - $50,000
   $51,000 - $75,000 $>75,000
6. **Please indicate your education level (circle one):**
   Less than high school
   High school diploma
   College diploma/certificate
   Undergraduate university degree
   Graduate university degree (Masters/Ph.D.)
7. **Do you have any diagnosed medical conditions? If yes, please list:**

Appendix I

Whole-body vibration (WBV) training program design for adults 60 years of age and older

Week	Day	# of sets on WBV	Exercise	Hz	Amp	Time	Rest	Total Time (mins)
1	1	6	SWLB	35	1	60s	60s	12
	2	7		35	1	60s	60s	14
	3	8		35	1	60s	60s	16
2	1	9		35	1	60s	60s	18
	2	9		35	1	60s	60s	18
	3	9		35	1	60s	60s	18
3	1	10		40	1	60s	60s	20
	2	10		40	1	60s	60s	20
	3	10		40	1	60s	60s	20
4	1	11		40	2	60s	45s	19.25
	2	11		40	2	60s	45s	19.25
	3	11		40	2	60s	45s	19.25
5	1	11	SWLB + DSE	45	1	60s	45s	19.25
	2	11		45	1	60s	45s	19.25
	3	11		45	1	60s	45s	19.25
6	1	11		45	1	60s	30s	16.5
	2	11		45	1	60s	30s	16.5
	3	11		45	1	60s	30s	16.5
7	1	11		45	2	60s	30s	16.5
	2	11		45	2	60s	30s	16.5
	3	11		45	2	60s	30s	16.5
8	1	11		45	2	60s	30s	16.5
	2	11		45	2	60s	30s	16.5
	3	11		45	2	60s	30s	16.5

Note. # of sets= Number of times on the vibration platform; Exercise=Exercises performed on vibration platform-Standing with legs bent (SWLB), and Dynamic Squat Exercises every other set (DSE); Hz=Vibration frequency (Hertz); Amp= Vibration amplitude (millimetres); Time:=Time of each set (seconds); Rest=time allocated for no vibration (seconds); Total Time= Total time of IG session (minutes).

Appendix J

The Rating of Perceived Exertion Scale (RPE CR-10; Borg, 1990).

Ratio	Perceived Exertion Rating
0	Nothing at all
1	Very weak
2	Weak (light exertion)
3	Moderate
4	
5	Strong (heavy extertion)
6	
7	Very Strong
8	
9	
10	Extremely Strong (almost maximal exertion)